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INFRARED SOURCES IN OBSCURED REGIONS

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SUMMARY

Two new infrared sources in the direction of dark nebulae in Taurus and Cygnus are reported and one known source re-examined. The new source in Taurus may be suitable for determining the infrared reddening law.

1. INTRODUCTION

The nature of the reddening law in the near-infrared is currently a matter of much debate. Most infrared sources which are sufficiently reddened for an accurate determination to be made cannot be relied upon because of the possibility of contamination by circumstellar dust emission. We have found two new infrared sources in obscured regions, and one of these is almost certainly unaffected by dust emission.

2. THE TAURUS DARK CLOUDS

An infrared source was found by Allen (1972) embedded in the Taurus dark clouds and close to the reflection nebula IC 2087. This infrared star is almost certainly the source of illumination of IC 2087. Allen was unable to distinguish two models for the source: (i) a B star reddened by 30 mag of interstellar extinction and (ii) a roughly G-type star with a dust cloud and no significant reddening. By using the Tenerife 1·5-m flux collector we have been able to secure improved positional and photometric data on the IC 2087 source. By offsetting to nearby SAO catalogue stars we derived the following 1950 positions which we consider reliable to better than $\pm 10''$ arc:

$$\alpha: 04^{h}\ 36^{m}\ 51^{s}\!\cdot\!9 \qquad \delta: +25^{\circ}\ 39'\ 29''.$$

Within the error circle is a faint star near to the limit of the Palomar Sky Survey red print and quite invisible on the blue print. This we believe to be the infrared source; we have identified it on Plate I. The new infrared magnitudes are given in Table I, and Fig. 1 illustrates the position of the source relative to the blackbody line and reddening vector on the *J–H*/*H–K* and *H–K*/*K–L* two-colour diagrams.

TABLE I

JHKL magnitudes of the sources

	J	*H*	*K*	*L*
IC 2087	10·38 ± 0·13	7·92 ± 0·05	6·20 ± 0·03	4·73 ± 0·08
Source Q	10·81 ± 0·11	8·14 ± 0·04	6·94 ± 0·03	6·31 ± 0·07
M1–99	9·48 ± 0·07	7·43 ± 0·03	5·67 ± 0·03	3·89 ± 0·08

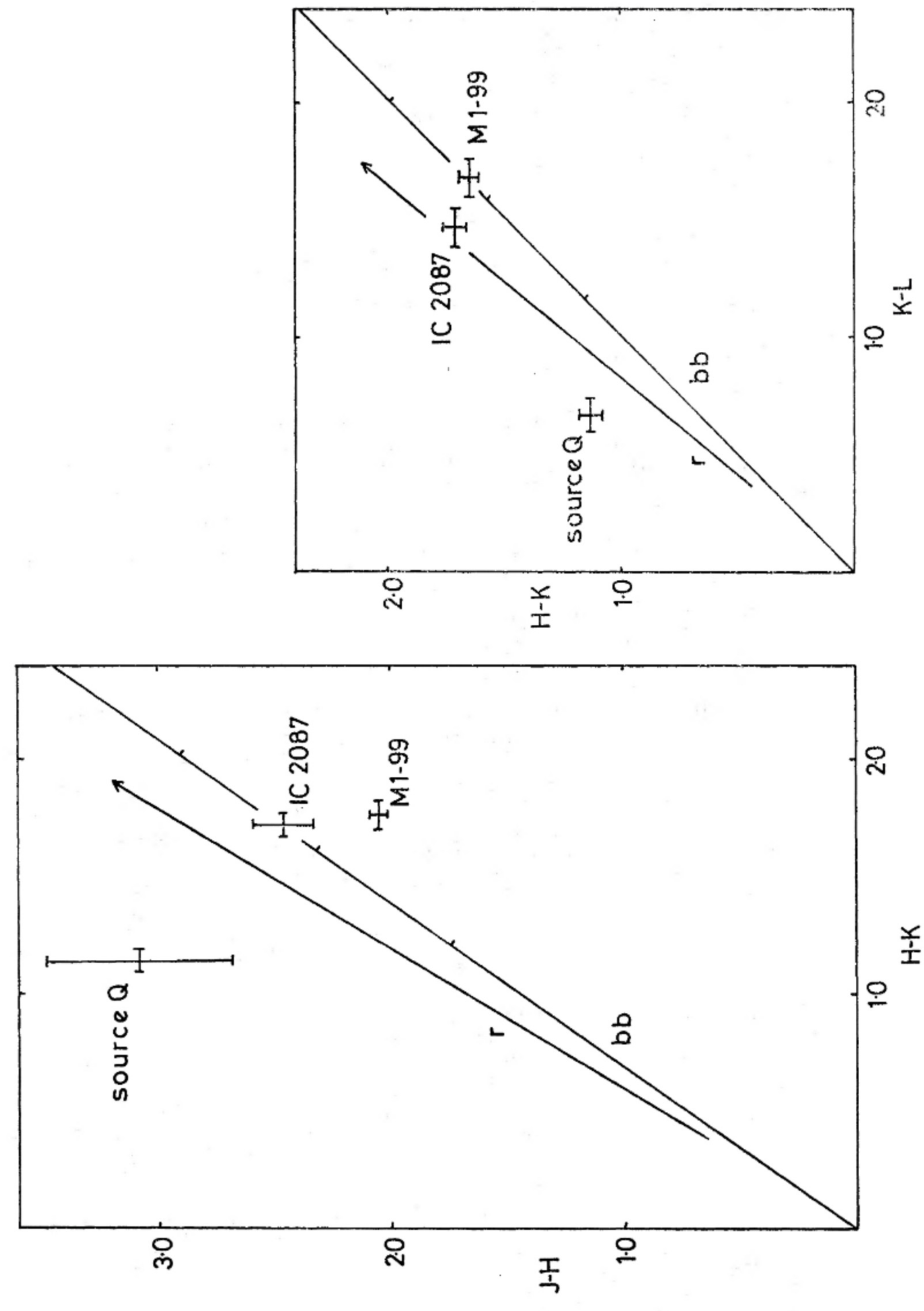

FIG. 1. *The two-colour diagrams for the sources discussed. bb is the blackbody line, ticked at* 1500, 1200 *and* 1000 *K. r is the van de Hulst no.* 15 *reddening law.*

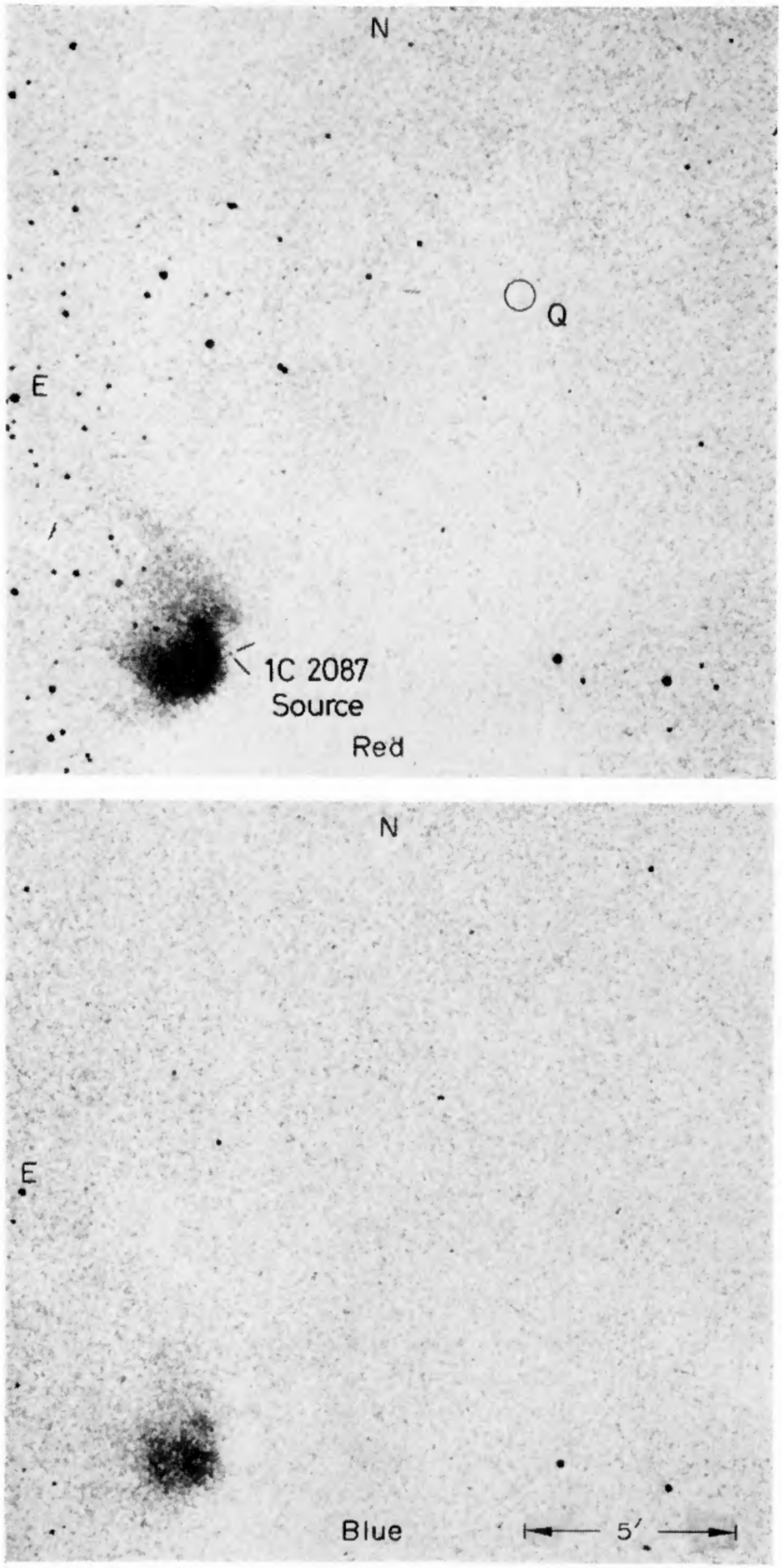

PLATE I. *Red and blue Palomar Sky Survey finding charts for the infrared sources in the Taurus dark clouds.*

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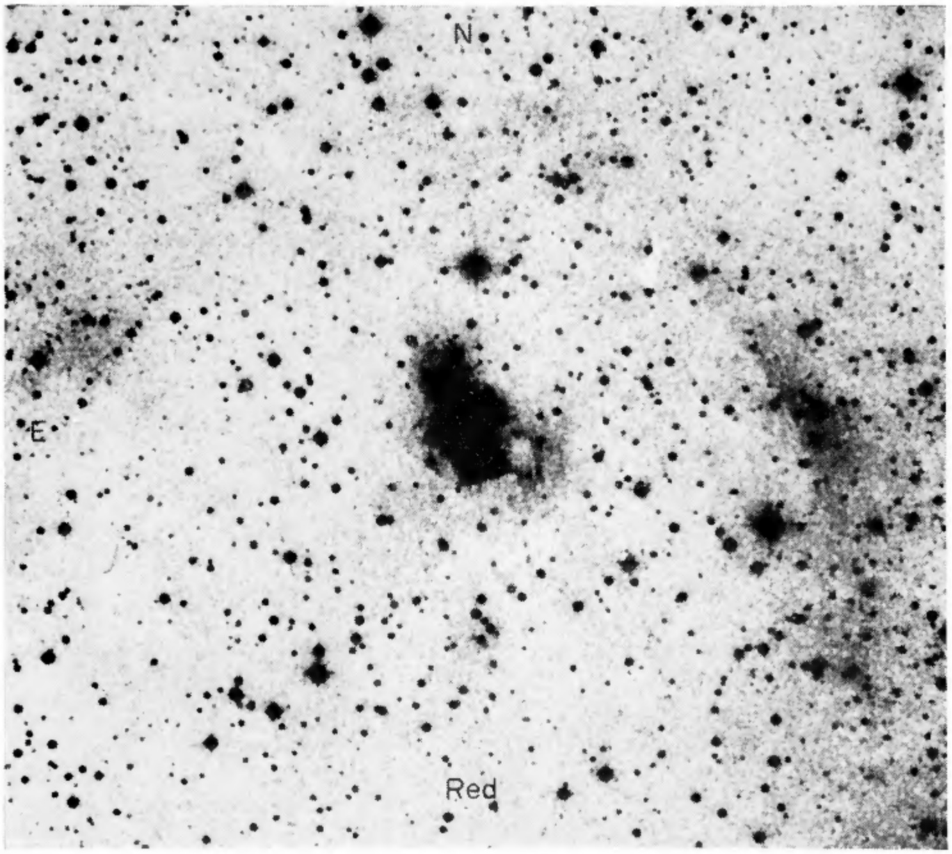

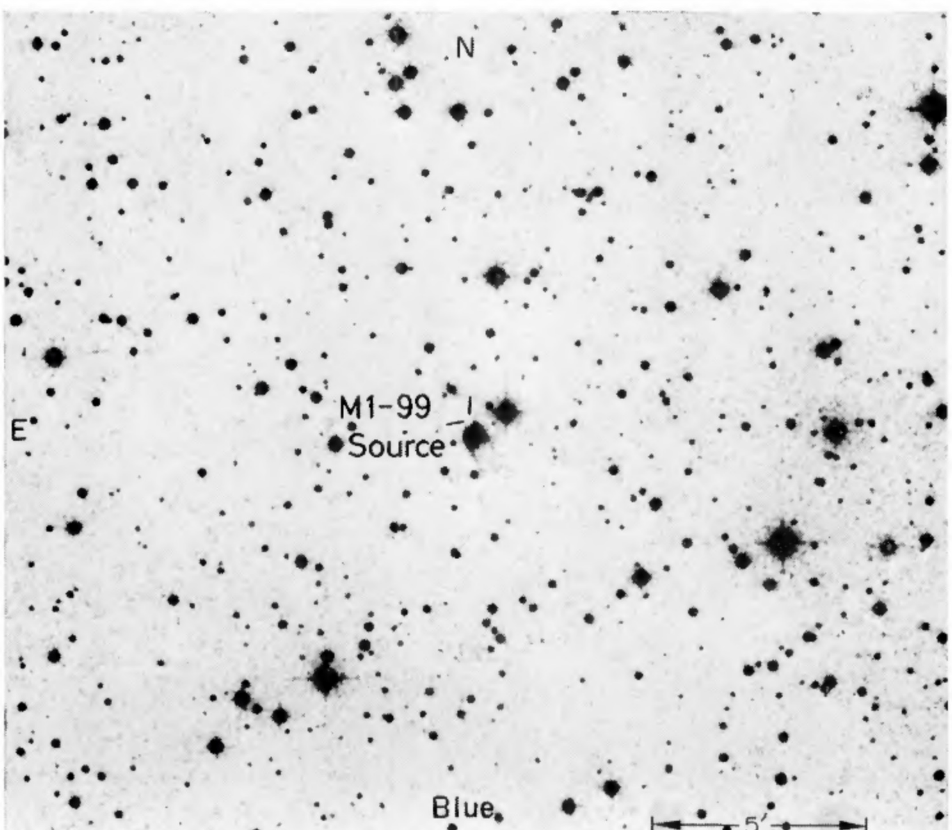

PLATE II. *Red and blue Palomar photographs of M1–99. Note the faint 'Barnard's loop' formation surrounding this nebula on the red print.*

We searched a considerable area of the Taurus dark clouds in a search for other infrared objects of similar 2·2-μm mag to the IC 2087 source. Our most interesting find, which we labelled source Q at the time of its discovery, lies approximately 12′ arc from IC 2087 at (1950):

$$\alpha\text{: } 04^{\text{h}}\ 36^{\text{m}}\ 22^{\text{s}}{\cdot}6 \qquad \delta\text{: } +25^{\circ}\ 47'\ 22''.$$

Because this source is fainter than IC 2087, our position may be no better than $\pm 15''$ arc. The magnitudes and colours of source Q are again given in Table I and on Fig. 1. Plate I shows that there is no identification for source Q on the Palomar prints.

Source Q occupies an unique position on the two-colour diagrams considerably above both the blackbody and (van de Hulst no. 15) reddening lines. No combination of normal stars and/or blackbodies can produce colours even remotely resembling those of this source. The only explanation we can offer is that the infrared reddening law in the Taurus dark clouds differs markedly from van de Hulst's (1949) no. 15 law, and that source Q experiences a considerable amount of reddening. Once we accept a peculiar reddening law, however, we cannot deredden the source to estimate its intrinsic colours. In particular, we cannot normally expect to be able to say whether circumstellar dust emission contributes to the redness of the object. In the case of source Q, the observed K–L index, ignoring any effect of reddening, is already much smaller than that of any known source with hot circumstellar dust emission and corresponds to a blackbody temperature in excess of 2000 K. The presence of dust emission significantly affecting the observed colours is therefore ruled out.

If source Q is a highly reddened normal star at a distance of at least 150 pc, the distance of the Taurus dark clouds (Joy 1945), its absolute L magnitude is at least zero, corresponding to a main sequence B star. Source Q is probably one of the very few B stars in the Taurus dark clouds. The intrinsic infrared colours of a B star are very small, so the observed colours arise solely by reddening. In this case we derive a reddening law approximately $E_{J-H} : E_{H-K} : E_{K-L} = 2{\cdot}2\ (\pm 0{\cdot}1) : 1{\cdot}0 : 0{\cdot}5$. The corresponding figures for the van de Hulst no. 15 law are 1·7 : 1·0 : 0·8. Glass & Penston (1975) found evidence that in the R CrA dark clouds $E_{J-H} : E_{H-K}$ is again 2·7 : 1·0. Such a reddening law might indicate the presence of more large particles than van de Hulst considered. Applying this reddening law to the first source in IC 2087 we find it dereddens into the domain of stars with dust emission and this we consider to be the most likely situation. On the assumption that the dust is not hotter than 1600 K, the reddening cannot exceed 60 per cent that of source Q and the luminosity is no greater than that of an F star unless there is unexpectedly strong emission at wavelengths longer than 3·5 μm.

3. OTHER AREAS

1. *Orion*

From an analysis of spectra of a bright rim in the Orion Nebula, Schmidt (1974) predicted the existence of an O star some 40′ arc east of the Trapezium hidden by a dark cloud. No source was found to a 2·2-μm mag of about 7 in a rectangle of 30′ arc east–west by 20′ arc north–south whose north-east corner lies at (1950) α: $05^{\text{h}}\ 36^{\text{m}}\ 03^{\text{s}}$, δ: $-05^{\circ}\ 12'{\cdot}5$. This search completely covered the area in which

Schmidt's proposed O star should lie and the ionization structure of his rim is therefore unexplained.

2. *Minkowski* 1–99

Plate II reproduces the red and blue Palomar Sky Survey prints of M1–99 (= Sharpless 106), a small emission nebula divided by a dark lane (Minkowski 1946). There is no visible source of excitation of the nebula, and the possibility that a star lies obscured in the dark lane and might be detected in the infrared was suggested to us by Dr G. H. Herbig. An infrared source has indeed been found within the dark lane and very close to the brighter portion of the nebula. The magnitudes and colours are given in Table I and Fig. 1. Despite the probable presence of considerable interstellar extinction due to obscuring material, the colours appear to be those of a star with circumstellar dust emission. The colour temperature, ignoring reddening, is 1100 K. Presumably the dust which gives rise to the infrared emission is some of the material forming the dark lane; this may lie in a flattened disc seen roughly edge-on.

We have no direct knowledge of the distance or luminosity of the source. To excite the emission nebula, however, it is probably an O or early B star. If our photometry includes most of the luminosity of the source, i.e. if there is no great excess at longer wavelengths—we can estimate the minimum distance to be 1·3 kpc for a B5 star. Distance estimates of Cygnus spiral arm clusters in this direction range from about 1·5 to 2 kpc.

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